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Dear Maged,

The members of the Zero Mercury Working Group (ZMWG) appreciate the opportunity to present comments on the planned content of the atmospheric emissions report required under the UNEP Governing Council 24th meeting Decision 24/3, paragraph 24.

Objectives of the Atmospheric Emissions Report

UNEP Governing Council Decision 24/3 requests that the Executive Director prepare a report including:

- Best available data on mercury emissions and trends, including where possible an analysis by country, region and sector;
- Modeling on a global scale and contribution of regional emissions to deposition; and
- Sector-based best practices for reducing mercury emissions.

Introduction

These comments focus on recommendations to achieve the first objective, namely, obtaining and analyzing the best available data on mercury emissions and trends. In summary, the ZMWG recommends that UNEP should:

- First and foremost, identify the most significant source-specific gaps or inadequacies in the UNEP Global Mercury Assessment and existing global mercury emission inventories, and attempt to fill those gaps to the maximum extent feasible, by

requesting data from industry and other sources, objectively assessing such data, updating source characterization in terms of numbers of sources and their size, and applying the UNEP toolkit methodology and other appropriate means. **This report will have greatly enhanced value if it is able to add substantively to what is already known, rather than summarize what is already available in the published literature.** In these comments, ZMWG identifies coal combustion, industrial ore processing, cement production and waste incineration as the priority sectors for updating source characterization data and developing improved quantitative global emission estimates.

- Derive global mercury emissions by **collecting actual emissions data** from existing sources or through additional monitoring, especially for poorly characterized sources, and then supplementing such data by estimating emissions using indirect techniques (e.g., using emissions factors and output data). The report must provide an accurate perspective of the relative contributions that mercury emissions sources make to the global mercury burden, in order to help prioritize actions and apply effective emission controls;
- Demonstrate the distribution of these emissions among the different species of mercury (elemental gaseous, reactive gaseous (divalent) mercury and particulate-bound mercury), and understand the circumstances that influence the relative mix of species, in order to better predict the potential for deposition and global cycling. Research on the nature of mercury released from different sources has burgeoned in the past few years, and the UNEP report should review and report on this literature.

Coverage of the Report

We assume that the UNEP Global Mercury Assessment¹ will be the starting point for the air emissions report. The GMA presented the following estimates for the major sources of atmospheric releases of mercury:

¹ United National Environment Programme (UNEP), Chemicals Programme. 2002. *Global Mercury Assessment*. Inter-organization Programme for the Sound Management of Chemicals. December.

[Table 6.1 of GMA]: Estimates of global atmospheric releases of mercury from a number of significant anthropogenic sources in 1995 (metric tons/year). Releases to other media are not accounted for here. *1

Continent	Stationary combustion	Non-ferrous metal production *5	Pig iron and steel production	Cement production	Waste disposal *2	Artisanal gold mining *4	Sum, quantified sources *3
Europe	186	15	10	26	12		250
Africa	197	7.9	0.5	5.2			210
Asia	860	87	12	82	33		1070
North America	105	25	4.6	13	66		210
South America	27	25	1.4	5.5			60
Australia and Oceania	100	4.4	0.3	0.8	0.1		100
Sum, quantified sources, 1995 *3,4	1470	170	30	130	110	300	1900 +300
Based on references:	Pirrone <i>et al.</i> (2001)	Pirrone <i>et al.</i> (2001)	Pirrone <i>et al.</i> (2001)	Pirrone <i>et al.</i> (2001)	Pirrone <i>et al.</i> (2001)	Lacerda (1997)	

Notes: 1 Releases to aquatic and terrestrial environments, as well as atmospheric releases from a number of other sources, are not included in the table, as no recent global estimates are available. See chapter 6 for description of issue.

2 Considered underestimated by authors of the inventory, see notes to table 6.10.

3 Represents total of the sources mentioned in this table, not all known sources. Sums are rounded and may therefore not sum up precisely.

4 Estimated emissions from artisanal gold mining refer to late 1980's/early 1990's situation. A newer reference (MMSD, 2002) indicates that mercury consumption for artisanal gold mining - and thereby most likely also mercury releases - may be even higher than presented here.

5 Production of non-ferrous metals releasing mercury, including mercury, zinc, gold, lead, copper, nickel.

Despite some subsequent efforts to update these emission sources,² the state-of-the-art analysis published by Swain et al. in *Ambio* in 2007 continued to use virtually the same data, suggesting that it remains tenuous:

“...it would be reasonable to assign an uncertainty of $\pm 30\%$ to total anthropogenic emissions, with some sectors embodying less uncertainty than average and some sectors more. It has been suggested that Hg emitted from global coal combustion has a $\pm 25\%$ uncertainty; nonferrous metal production $\pm 30\%$; waste disposal and incineration has uncertainty up to 500%; and that Hg use in artisanal and small-scale gold production is too poorly understood to allow a quantitative uncertainty factor to be assigned.”³

² For example: Pacyna, J.M. and Pacyna, E.G. 2005. Anthropogenic sources and global inventory of mercury emissions. In: M.B. Parsons and J.B. Percival (eds.): *Mercury: Sources, Measurements, Cycles, and Effects*. Mineralogical Association of Canada.

³ Swain EB, P Jakus, F Lupi, P Maxson, J Pacyna, A Penn, G Rice, S Spiegel, M Veiga. “Socioeconomic Consequences of Mercury Use and Pollution.” *Ambio: A Journal of the Human Environment Vol XXXVI No 1*. ISSN 0044-7447. Royal Swedish Academy of Sciences. February 2007.

The brief analysis provided later in these comments demonstrates how much work remains to be done on these emission estimates, and shows that, among other problems, the data above seriously underestimate mercury emissions from nonferrous metal production and waste incineration. We recommend that UNEP spend most of its “atmospheric emissions effort” developing newer and better estimates for large sources such as coal combustion, nonferrous metal production, cement production and waste incineration, with a focus on the developing world (particularly in Asia) where these sources are growing the fastest.

As described in the UNEP toolkit⁴ for the development of emissions inventories in individual countries, the general procedure for estimating emissions requires activity rates for processes that generate mercury emissions, input factors that describe the mercury content of materials used in those processes, and output distribution factor which describe the fraction of the input mercury that is released to different environmental pathways, including air. For a global atmospheric emissions report, new data are critically needed in all three of these areas, especially in developing countries where the rate of growth of coal combustion and industrial process sources is very high, and where output distribution factors (e.g., emission factors) from the developed world may not be applicable, due to differences in technologies used and controls applied. UNEP will need to collect these new data not only from environmental and other government agencies within countries, but from a wide range of nongovernmental sources such as private sector trade associations, energy and industry forecasts, industry financial investment reports, and academic institutions.

In addition, as is evident from the table above, estimates are needed for emissions resulting from the manufacture and use of products containing mercury, although Swain et al. (2007) did venture a global estimate of mercury emissions during manufacturing. Finally, additional important sources, such as vinyl chloride monomer production and chlor-alkali facilities, will need to be addressed, at least qualitatively, in the emissions report, so that they are not lost from subsequent discussions on emission reduction strategies. Some quantitative estimates are available from the chlor-alkali industry in various parts of the world, but these are typically estimates or incomplete measurements that may not reflect actual emissions (see discussion below), and certainly may not be extrapolated to estimate actual emissions across the industry. Instead, it may be desirable to provide a range of estimates of poorly characterized sources, to indicate both best estimates and possible worst case estimates.

⁴ UNEP. 2005. *Toolkit for Identification and Quantification of Mercury Releases*. IMOC – Inter organizational Programme for the Sound Management of Chemicals. A cooperative agreement among UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD. Geneva, Switzerland, November 2005.

Considerations for Priority Mercury Source Categories

Coal-fired power plants

Since the GMA 2002, which already noted coal-fired power plants as the largest source of mercury air emissions worldwide, there has been an explosive growth in the number of coal-fired power plants, and the mercury contribution from this source category has surely increased as well. Thus, a major focus of the report must be a thorough quantitative characterization of this source, with special attention to estimates of emissions in rapidly developing countries. To evaluate the current mercury emissions from coal-fired power plants, UNEP will need up-to-date information on the number of plants, their capacity and the current pollution control devices in place, if any, as well as robust data on the range of mercury content in coal supplies, especially in regions where the number of coal-fired plants have increased the most. Energy industry and public utility reports and forecasts will be invaluable to estimate the number of sources in each combustion category, their size, type and operating conditions that will affect the emissions rates.

Non-Ferrous Industrial Ore Processing

Industrial-scale ore mining and processing is a very significant mercury emission source, because mercury occurs naturally as a trace contaminant in many types of ores. As shown in the table above, the GMA cited emissions of about 170 metric tons per year from this sector. However, more recent emissions data suggest that this figure is at least twice that, and likely even higher. Because the sector is potentially so important, yet poorly characterized to date, the ZMWG made its own estimate of potential mercury emissions from these sources. Using published and calculated emission factors together with quantities of ore processed worldwide⁵, we calculated a best estimate of about 430 tons per year of mercury emitted from non-ferrous ore processing, with an upper bound estimate of 510 tons per year, making this source one of the largest atmospheric contributors. Appendix 1 provides details of these calculations.

We urge UNEP to focus its effort in this category on those mining activities that matter most: primary zinc, copper, and lead smelting; and industrial gold mining. We further urge UNEP to collect more data on the mercury content of ores worldwide (much of this data may already be available from industry and government sources); on the number, size and location of the larger smelters and mines in these sectors (available from industry sources and trade publications); and on the nature of relevant pollution control devices at these facilities (available from public and private sources), in order to make a more detailed estimate of emissions from this source. For these industries particularly, application of different region-specific emission factors will be required.

⁵ Production figures for all ores are taken from US Geological Survey Minerals Yearbooks, available at: <http://minerals.usgs.gov/minerals/pubs/commodity/> Details on these calculations are given in Appendix 1.

Cement kilns

Mercury is found in the raw materials used to make cement, such as limestone. Cement is one of the most energy intensive industries in the world, and the amount of coal used to fuel the process is also substantial. Alternative fuels used in cement kilns (fly ash, hazardous wastes, waste oils, etc.) may also contain significant amounts of mercury. These “alternative fuels” have become more common as a way to decrease the cost of fuel and to reduce the consumption of raw materials by the process.

Mercury emissions monitoring data from cement kilns are limited. Therefore, the collection of new emissions data is important for this source. Because the mercury content of limestone, coal and alternative fuels can vary significantly, UNEP should request from governments and the cement industry emissions monitoring under a range of conditions and fuel types. International cement industry associations should have basic data on where the biggest kilns are located, and their production capacity. Local information on mercury content of limestone and coal (and/or alternative fuels) near these biggest kilns should also be requested.

UNEP should also be careful about extrapolating from emission rates from Western cement production practices to those in China, which is the world’s largest cement producer by far. In China, around ninety percent of the cement kilns are vertical shaft cement kilns, a technology generally not used in Western countries. Importantly, these kilns are very energy inefficient, and require more energy per unit output. Therefore, the mercury emissions from coal consumption at these plants per unit of cement produced is also likely to be much higher than for rotary kilns.

Waste Incineration

Combustion of waste is also a major source of mercury emissions to the global environment. The GMA reported widely varying estimates of mercury from waste, from 140 to 2100 tons per year, with sewage sludge contributing another 15 to 60 tons (see Table 6.9 of the GMA). The wide range represented by these figures reflects the variability and uncertainty in the mercury emissions from waste combustion.

- In municipal waste streams, mercury can come from discarded products (batteries, old paints, auto switches), as well as natural and man-made impurities in high-volume materials (plastics, packaging, etc.). The mercury emitted will depend on the amount of these materials in the waste stream, and this will vary dramatically from country to country.
- Medical wastes can contain mercury from discarded medical products and chemicals. Because medical wastes are very often incinerated in order to safely manage biological hazards, any mercury wastes mixed in will also be incinerated, and the mercury released to the atmosphere.

- Municipal wastewater sludge will also contain mercury in proportion to the mercury content of municipal and industry wastewater, which will in turn depend on the amount of mercury discharges allowed to sewage systems.
- The mercury content in the hazardous waste stream originates primarily from intentionally used mercury in discarded products and process waste. Some hazardous waste is incinerated and hazardous wastes may also be burned in cement kilns as alternative fuel.

As the GMA states, the releases from waste are difficult to characterize because of the variability of the waste stream, and “how much this amounts to on a global level has not been seriously estimated.” Further, incidental releases from spills and breakages have also not been well-described.

Because of this variability of mercury content in waste streams, consistent emissions rates will be hard to estimate. However, UNEP could derive estimates indirectly based on the tons of mercury contained in household and medical products, the fraction of those products disposed each year, and the fraction of those wastes incinerated. If possible, UNEP should also try to collect information on the number of waste incinerators and their capacity in each country, so that the country-level waste stream data can be matched to country-level incineration data, at least for the larger countries.

Other Sources

Mercury products

Waste incineration is only one way mercury is released from mercury products. Other ways include emissions during manufacture of the products, breakage during use (i.e., thermometers), breakage during waste handling prior to disposal, breakage at the disposal location (landfill, open dump, open burning), and the land spreading of sewage sludge. For many products, breakage during waste handling will be the typical means by which mercury is released (lamps, some measuring devices), because the product cannot withstand significant weight or pressure. Similarly, it is also important to take stock of emissions from poorly controlled factory operations, such as facilities in the developing world manually adding elemental mercury by spoon or eye dropper to blood pressure cuffs and compact fluorescent lights. To date, other than the rough estimate of Swain et al. (2007) mentioned above, global emission inventories have not adequately accounted for industrial emissions or taken other pre-disposal releases into account.

Some states in the United States have developed product end-of-life release estimates for certain mercury products by assuming a certain level of breakage during waste handling.⁶ We urge UNEP to examine these breakage estimates and associated waste release estimates, because they represent the most mature thinking in this area we have encountered.

⁶ See e.g., the New Jersey inventory available at http://www.state.nj.us/dep/dsr/mercury_task_force.htm, particularly volume 3, chapter 3

When evaluating potential emission controls for mercury products, UNEP should be cognizant of the limited ability of all nations to prevent mercury emissions from pre-disposal releases, and of developing nations in particular to prevent or even minimize emission releases during disposal. In fact, the waste disposal infrastructure in most parts of the world will not lend itself to the segregation, handling, recycling, or pollution control measures necessary to manage mercury waste products safely and effectively. Accordingly, UNEP must make the critical link between this waste management emission control challenge and the need to phase out the use of mercury-added products as the optimal means of meeting this challenge.

Chlor-alkali plants

As of 2004, there were approximately 150 chlor-alkali plants worldwide that still use mercury cell technology in the manufacture of chlorine and caustic soda. Some countries require these plants to submit emissions data, or to conduct a mass-balance accounting of mercury in their processes. However, an NRDC study in the US compared the amount of emissions reported to the amount of mercury purchased to replace mercury in the cells and highlighted significant discrepancies,⁷ as did a recent status report on the chlor-alkali industry in the EU.⁸ The industry has claimed that this “missing” mercury is contained within the process machinery, stored onsite or otherwise accounted for. However, the NRDC study, as well as independent monitoring of some sites in the EU, has shown significant fugitive emissions from near cell rooms and waste piles – clearly showing that mercury is escaping into the air⁹. Further efforts are needed to better characterize the actual losses to the air from this source. Given the emission uncertainties, which are not likely to be resolved in this report, UNEP will need to acknowledge these uncertainties qualitatively and apply a wide emission range for this sector.

UNEP needs also to be careful not to casually apply developed country emissions factors to developing country processes to estimate emissions worldwide for this sector. For example, in India, it was reported that even the best plant there loses up to 25 times more mercury than the global best figure: specific mercury loss was reported in the range of 0.069 to 0.35 kg per tonne of NaOH produced.¹⁰ More recent data showing lower emissions has been provided to UNEP by the Indian chlor-alkali industry via the World Chlorine Council, and this has been assessed in the UNEP Trade report.¹¹

⁷ Natural Resources Defense Council. 2006. *Lost and Found: Missing Mercury from Chemical Plants Pollutes Air and Water*. April 2006.

⁸ Concorde East-West. 2006. *Status Report: Mercury-cell Chlor-alkali Plants in Europe*. Prepared for the European Environmental Bureau. October.

⁹ Ibid; also see Southworth et al., “Fugitive emissions from a chlor-alkali factory: sources and fluxes to the atmosphere.” *Atmospheric Environment* 38: 597 (February 2004), and European Environmental Bureau, *Risky Business! No Need for Mercury in the Chlorine Industry*. Special Report, October.

¹⁰ From Centre for Science and the Environment, Green Rating Project. 2002. *Environmental Rating of the Indian Caustic-Chlorine Sector*, pp.56-57.

¹¹ PA Maxson, *Summary of Supply, Trade and Demand Information on Mercury*, analysis requested by UNEP Governing Council decision 23/9 IV, United Nations Environment Programme – Chemicals.

VCM in China

The use of mercury as a catalyst in the manufacturing of VCM is one of the major intentional uses of mercury in the world, but this use is concentrated in one country: China.¹² Although the sector has been reported to use roughly 700 tons of mercury per year, the fate of this mercury is not well understood. Because mercury is used as a catalyst, it is not consumed in reaction. However, it clearly escapes the process reaction, as activated carbon catalyst beds become routinely exhausted when mercury concentrations drop to low levels. UNEP should continue to work cooperatively with the Chinese government and Chinese VCM manufacturers to obtain data on the fate of mercury in this sector, both at the VCM plants and at catalyst recycling facilities. If the fate of the mercury cannot be conclusively determined before finalization of this report, UNEP should identify qualitatively the principal potential mercury release points at the VCM plants and recycling facilities, and provide a wide range of release estimates based upon potential scenarios.

Artisanal and Small Scale Gold Mining

Artisanal and small scale miners worldwide use mercury to amalgamate gold from ores. Once the amalgam is formed, the mercury is burned off to leave the solid gold. UNIDO estimated the total amount of mercury released to air from this practice as possibly 300 tons per year (although it was admitted that there is considerable uncertainty in this estimate), making it a significant source (see also Swain et al., 2007). Given the very dispersive, often secretive and illegal nature of the practice, we do not recommend that UNEP expend its limited time and resources to try to make a better estimate than UNIDO has already provided. This source should be acknowledged in the report as a major source which continues to grow as the number of miners increases worldwide.

Fuels Other than Coal

More information is needed about the mercury content and emissions of mercury from oil and natural gas in order to better judge the magnitude of this emissions source. As noted in the GMA, these materials are used in huge quantities throughout the world, so even relatively small concentrations could still result in a meaningful amounts of mercury contributed to the global environment. UNEP should request these data from the oil and gas industry, as well as data on the prevalence and effectiveness of measures to remove mercury from natural gas. Even as recently as the UNEP mercury workshop in Bangkok,¹³ the Malaysian delegate highlighted the possibly very significant gas-field related emissions of mercury in her country.

Geneva, November 2006.

¹² Ibid.

¹³ UNEP Workshop to Reduce Mercury Use and Release in Products for the Asia Pacific, Bangkok, Thailand, 17-19 May 2007.

Iron and Steel

Mercury may be emitted from various points in an integrated iron and steel processing system, including the sinter plant and blast furnaces. Like with ore processing, the emissions will depend on the content of the ore and the amount of ore used, as well as on whether scrap metal containing mercury (from autos and appliances) is used as feedstock. Particular attention should be paid to secondary smelters generally, due to the mercury content of switches and relays in the scrap metal.

Conclusion

Preparing the atmospheric mercury emissions report is a challenging but critically important task; a thorough understanding of the atmospheric sources of global mercury pollution will provide the critical factual basis for devising effective emissions control strategies. We strongly urge UNEP to use this opportunity to develop new information about emissions, rather than simply summarize what is already known from other sources. UNEP should not hesitate to request the necessary resources from interested governments in order to collect new information and to prepare the most comprehensive report possible.

Appendix 1. Calculation of Mercury Releases from Non-Ferrous Industrial Ore Processing

Industrial-scale ore mining and processing can release mercury into the environment, because mercury naturally occurs with many types of ores. The UNEP Global Mercury Assessment¹⁴ identified industrial ore processing as an important contributor to the global pool of mercury and estimated emissions of about 170 metric tons per year from this sector. However, more recent emissions data suggest that this figure is almost certainly under-estimated. Because this sector is potentially a very important contributor to overall global mercury atmospheric emissions, the ZMWG has calculated its own estimate of the total tons of mercury emitted from this source each year. This Appendix details the methods and data sources used to derive those estimates, and also presents the results of the calculations in detail.

Ore processes that produce mercury

The processing of zinc, copper, lead, gold, nickel, iron and alumina are likely to release mercury because these ores often contain significant concentrations of mercury and because thermal methods are used to process them. Ore processes which involve high heat, such as roasting and smelting, are particularly likely to release mercury to the environment. Other thermal units which are commonly used in gold mining, such as retorts, carbon regeneration kilns, electro-winning devices, and autoclaves, may also release mercury.

Occurrence of high-Hg-content ores

Mercury content of ore is dependent on the particular geology of the mineral deposits. “Belts” of high mercury deposits are known to occur in the Western US and Canada, Eastern Australia, certain areas of central China and Peru¹⁵. These areas generally correspond to geographic areas that produce most of the world’s gold: four of the five largest gold producers worldwide in 2004 were Australia, the US, China and Peru¹⁶ (South Africa was the largest producer). These high-mercury areas also correspond to major zinc producing regions: in 2004, China alone accounted for about a quarter of all world zinc mining, and Australia, Peru, Canada and the US combined accounted for another 40 percent. It is important to remember, though, that high mercury content has been documented in various ore deposits all over the world¹⁷, and that mercury content can vary dramatically even within a geographic area, so it is critical to measure mercury content and monitor mercury emissions everywhere that ore mining and smelting operations occur.

¹⁴ United National Environment Programme (UNEP), Chemicals Programme. 2002. *Global Mercury Assessment*. Inter-organization Programme for the Sound Management of Chemicals. December.

¹⁵ Rytuba, J. 2003. Mercury from mineral deposits and potential environmental impacts. *Environmental Geology* 43:326-338.

¹⁶ USGS Minerals Yearbook, 2005 for Gold.

¹⁷ Schwartz, MO. Mercury in zinc deposits: economic geology of a polluting element. *International Geology Review* 39(10): 905-923. Table 3.

While emissions from gold processing are likely to occur near gold mining sites, emissions from processing of zinc ores occur where the zinc is smelted. Because zinc ore concentrates are shipped from zinc mines to smelting facilities all over the world, high levels of mercury emissions can occur anywhere the smelters are located. Table 1 identifies some of the largest zinc smelters in the world (with those production capacity >100,000 metric tons per year) and their capacities as of 2003.¹⁸ The largest of these zinc smelters are located in Spain, Korea, and China.

¹⁸ Table summarized from International Lead and Zinc Research Organization (ILZRO) *World Directory 2003: Primary and Secondary Zinc Plants*.

**Table 1. Largest Primary Zinc Smelters Worldwide 2003
(Greater than 100,000 Metric Ton Capacity)**

Country	Company	Location	Year Built	Capacity (000 MetricTons)
Australia	Pasminco	Risdon, Tasmania	1916	240
	Pasminco	Cockle Creek, NSW	1961	110
	Sun Metals	Townsville, Queensland	1999	200
Belgium	N.V. Umicore	Balen	1935	255
Brazil	Cia. Mineira de Metais	Tres Marias	1969	160
Canada	CEZinc	Valleyfield, Quebec	1963	260
	Falconbridge	Timmins, Ont	1972	145
	Hudson Bay Mining	Flin Flon, Manitoba	1930	114
	Teck Cominco	Trail, British Columbia	1916	290
China	Baiyin Zinc	Baiyan, Gansu	1991	200
	Huludao Lianshanqu Zinc	Huludao, Liaoning (vertical retorts)	1978	200
	Huludao Lianshanqu Zinc	Huludao, Liaoning (electrolytic)	1995	165
	Zhuzhou Lead/Zinc	Zhuzhou, Hunan	1959	350
Finland	Outokumpu	Kokkola	1969	260
France	Umicore France	Auby-les-Douai	1975	245
Germany	Metaleurop Weser GmbH	Nordenham, Lower Saxony	1972	135
	Ruhr-Zink GmnH	Dattelin, North Rhine – Westphalia	1968	120
	Sudamin Investment GmbH	Duisburg, North Rhine-Westphalia	1965	100
Italy	Portovesme SrL	Porto Vesne	1984	110
Japan	Akita Zinc Co.	Iijima, Akita	1972	200
	Hachinohe Smelting Co	Hachinohe, Aomori	1969	118

Table 1. Largest Primary Zinc Smelters Worldwide 2003 (Greater than 100,000 Metric Ton Capacity)				
Country	Company	Location	Year Built	Capacity (000 MetricTons)
	Toho Zinc Co.	Annaka, Gunma	1937	139
Kazakhstan	Kazzinc	Ust-Kamenogorsk	1947	249
	Kaz-Tyumen	Leninogorsk	1966	108
Korea	Korea Zinc Co.	Onsan, Kyoungnam	1978	420
	Youngpoong Corp.	Sukpo, Kyoung Buk	1970	270
Mexico	Industrial Minera Mexico SA	San Luis Potosi	1982	113
	Met-Mex Penoles SA	Torreon	1975	250
Namibia	Anglo American	Oranjemund	2003	150
Netherlands	Budel Zinc	Budel-Dorplein	1974	220
Norway	Outokumpu	Eitheim	1929	145
Peru	Cajamarquilla Zinc	Cajamarquilla	1981	120
Russia	Chelyabinsk Zinc	Chelyabinsk	1935	200
South Africa	Springs Zinc	Springs, Gauteng	1969	118
Spain	Asturiana de Zinc SA	Aviles, Asturias	1960	460
Thailand	Padaeng Industry Public Co	Tak	1984	105
UK	Britannia Zinc	Avonmouth	1967	115
USA	Big River Zinc	Sauget, Ill	1941	105
	Pasminco	Clarksville, TN	1978	115
	Zinc Corp. of America	Monaca, PA	1930	160
Uzbekistan	Almalyk Mining and Metallurgy	Almalyk	1971	120

Source: ILZRO. *World Directory 2003: Primary and Secondary Zinc Plants.*

Emissions estimates

The amount of mercury released from ore processing worldwide can be estimated using (1) published and calculated emission factors and (2) figures on the metric tons of ore processed worldwide.

Emissions Factors

The amount of mercury emitted during ore processing varies, depending on the mercury content of the ore and the particular processes used. For zinc, Pacyna and Pacyna (2002) estimated that mercury is emitted at a rate of between 7.6 grams per metric ton of zinc smelted in developed countries to 20 grams per metric ton in some developing countries.¹⁹; More recent evidence, however, shows much higher releases of mercury from zinc smelters. Streets et. al (2005) found that zinc smelters in China emitted an average of 86 grams per metric ton of zinc ore smelted, which is four times higher than the values reported by Pacyna and Pacyna for Asian countries (the upper bound value from Streets et al. was 156.4 grams per metric ton)²⁰. In our calculations for emissions from zinc smelting, we used the following emissions factors:

- ▶ 20 g Hg/metric ton Zn for developing countries²¹
- ▶ 7.6 g Hg/metric ton Zn for industrial countries²²
- ▶ 86.6 g Hg/metric ton Zn for China²³

Pacyna and Pacyna (2002) also estimated mercury emissions rates in grams per metric ton of production for lead and copper smelting. For lead, the emission rate was estimated to be 3.0 g/t, while for copper, the emissions rate was estimated to be 10 g/t in developing countries (Africa, Asia, South America) and 5.6 g/t in industrial countries (Europe, North America, Australia).²⁴

Recent data from US gold mines showed higher mercury emissions than suspected previously. In 1999, the US government first required reporting of emissions from the mining sector under the Toxics Release Inventory (TRI); these reports showed that more than six metric tons of mercury were released from gold mines alone, which represented

¹⁹ Pacyna E. and Pacyna. J. Global emissions of mercury from anthropogenic sources in 1995. *Soil, Air and Water Pollution* 2002, 137, 149-65.

²⁰ Streets et al 2005. Anthropogenic mercury emissions in China. *Atmospheric Environment* 39: 7789-7806.

²¹ Pacyna, E.G., and J.M. Pacyna, Global Emission of Mercury from Anthropogenic Sources in 1995, *Water, Air, and Soil Pollution* 137: 149–165, 2002.

²² *Ibid.*

²³ Streets D.G., J. Hao, Y. Wu , J. Jiang, M. Chan, H. Tian, and X. Feng (2005) Anthropogenic mercury emissions in China, *Atmospheric Environment* 39 (2005) 7789–7806.

²⁴ Pacyna, E.G., and J.M. Pacyna, Global Emission of Mercury from Anthropogenic Sources in 1995, *Water, Air, and Soil Pollution* 137: 149–165, 2002.

about 46 percent of all mercury air emissions reported that year²⁵. Since 1999, gold mines have voluntarily reduced emissions dramatically. By 2004, air emissions from mining reported to the TRI dropped to just over 2 metric tons.²⁶ The captured mercury can often be sold as commodity mercury on the global market (termed mercury “by-product”); however the total amount historically captured and sold by US gold mines on the open market is not reported publicly. Some voluntary data submitted by the gold mining industry in the US suggest that the amount of mercury by-product captured and sold by gold mines in the US has been on the rise since 2000, corresponding to the timeframe when emissions have been reduced.²⁷

To estimate mercury emissions factors from gold mining, we divided total Hg air emissions reported to TRI by gold mining facilities (SIC Code 1041) every year from 2000 to 2004 by total U.S. gold production for the corresponding year as found in the USGS *Minerals Yearbook*.

$$\text{Atmospheric Hg emissions reported to TRI} \div \text{US gold production} = \text{Hg emissions factor}$$

Using data collected during 2000, presumably before new emissions controls were installed, the emission rates from US gold mines were about 16,048 grams of mercury per metric ton of gold produced; using 2004 data, presumably after new controls were installed, emissions rates dropped to 8,663 grams/metric ton of gold. The average for the period 2000-2004 is 12,551 g Hg per metric ton of gold

Hg air emissions factors: Applying USGS production data from 2000-2004 to TRI data for the corresponding year					
Year	Hg emissions (pounds)	Hg emissions (grams)	Au production (kilograms)	Au production (metric tons)	Hg emissions factor (g Hg/metric ton Au)
2000	12488.92	5664878.822	353,000	353	16047.82
2001	12188.86	5528773.895	335,000	335	16503.80
2002	8740.88	3964796.475	298,000	298	13304.69
2003	5031.05	2282045.893	277,000	277	8238.43
2004	4927.231	2234954.387	258,000	258	8662.61
Average:					12,551.47

Sources:

U.S. Environmental Protection Agency, *Toxics Release Inventory*, <http://www.epa.gov/triexplorer>.

U.S. Geological Survey, *Minerals Yearbook*, <http://minerals.usgs.gov/minerals/pubs/myb.html>.

²⁵ Metal mining companies were required to submit their first reports in 1999. These reports contained 1998 data. Gold mining released 13,568 pounds (6.8 short tons, or about 6.2 metric tons) of mercury to air in 1998. This is 46% of the total air emissions of mercury reported to TRI that year (29,572 pounds or 14.8 short tons). Available on the web at <http://www.epa.gov/triexplorer/>

²⁶ TRI emissions data, 2004. Available on the web at <http://epa.gov/triexplorer>

²⁷ Jones, G. and Miller G. 2005. *Mercury and Modern Gold Mining in Nevada*. Final report to US EPA Region IX, Dept of Natural Resources and Environmental Sciences, University of Nevada, Reno. Table D.2. Byproduct mercury production in Nevada is now required under state law, beginning this year.

Ore Production Figures

Data on the primary production of each type of non-ferrous ore in each country were obtained from the 2004 USGS Minerals Yearbooks²⁸ for each ore. Because emissions factors have been shown, in general terms, to have some relationship to whether a country is industrialized or not, we obtained the list of countries that were considered “developed” (industrial) from the CIA *The World Factbook*.²⁹ For zinc smelting, some countries only reported only total zinc production figures, rather than primary smelting, where most mercury emissions are expected to occur. Primary production for industrialized countries where only total production was reported was estimated by multiplying total production by 0.75 based on the average of the fractions of primary to total production observed in the United States and Japan. For all other countries where only total production figures were available, we estimated primary production by multiplying total production by 0.9, based on the fraction of primary to total production observed for countries in the USGS data.

Results

To estimate mercury emissions for these sectors in 2004, we multiplied the production rate in each country by the applicable emissions factor. Rather than apply a single emissions factor to all countries within a continent, we again used the CIA *World Factbook* to determine which countries to consider industrial when deriving a best estimate of mercury emissions.³⁰ To calculate low-end estimates of mercury emissions, industrial country emissions rates were applied to all producing countries. To calculate high-end estimates, developing country emissions rates were used for all countries, except China. An emissions factor calculated specifically for China by Streets et. al (2005) was applied when calculating best and high-end estimates.³¹

The resulting estimated metric tons of mercury emissions are summarized in Table 2.

²⁸ U.S. Geological Survey, *Minerals Yearbook*, <http://minerals.usgs.gov/minerals/pubs/myb.html>.

²⁹ Central Intelligence Agency (CIA), 2006. *The World Factbook*, Appendix B, <https://www.cia.gov/cia/publications/factbook/>

³⁰ Ibid.

³¹ Streets D.G., J. Haob, Y. Wuc , J. Jiangb, M. Chand, H. Tianb, and X. Feng (2005) Anthropogenic mercury emissions in China, *Atmospheric Environment* 39 (2005) 7789–7806.

Table 2. Estimates of Mercury Emissions from Ore Processing Worldwide

Metal	Primary production, 2004 ^a (metric tons)	Hg emissions (metric tons)		
		Best estimate	Lower-bound estimate	Upper-bound estimate
Copper	13,874,100	116.4 (5.6, 10) ^b	77.7 (5.6)	138.7 (10)
Gold	2,430	30.4 (12,500) ^c	21.0 (8,660) ^d	32.3 (13,300) ^e
Lead	3,250,979 ^f	9.8 (3.0)	9.8 (3.0)	9.8 (3.0)
Zinc	8,799,439 ^g	273.9 (7.6, 20, 86.6) ^h	68.5 (7.6)	330.1 (20; 86.6) ⁱ
Total:		430.5	177.1	510.9

Emissions factors shown in (). All emissions factors are in g Hg/metric ton of production.

Hg emissions were calculated by multiplying production by the emissions factor and converting the result to metric tons.

^a Based on: U.S. Geological Survey, Minerals Yearbook, 2004, <http://minerals.usgs.gov/minerals/pubs/myb.html>.

^b 10 g Hg/metric ton Cu for developing countries; 5.6 g Hg/metric ton Cu for industrial countries

^c Average derived from U.S. EPA TRI and USGS 2000-2004 data

^d Derived from EPA TRI and USGS 2004 data (post-Hg reductions)

^e Derived from EPA TRI and USGS 2002 data (pre-Hg reductions)

^f When primary lead production was not reported, it was assumed that 50 percent of the country's total production was primary.

^g For developing countries for which primary zinc production was not reported, primary production was estimated by multiplying total production by 0.9 based on the fraction of primary to total production in other countries (exception: all of Namibia's reported production was considered to be primary). For industrialized countries this was done by multiplying total production by a factor of 0.75 based on the average of the fractions of primary to total production in the United States and Japan.

^h Emissions factors: 7.6 g Hg/metric ton Zn for industrial countries; 20 g Hg/metric ton Zn for developing countries; 86.6 g Hg/metric ton Zn for China

ⁱ Emissions factors: 20 g Hg/metric ton Zn for all countries except China; 86.6 g Hg/metric ton Zn for China

These calculations suggest that gold and zinc processing alone may release about 90 to 360 metric tons of mercury per year, mostly from zinc processing. Copper and lead processing could add an additional 90 to 150 metric tons per year. The total mercury emissions from ore processing is between 177 to 510 metric tons per year, with a best estimate of around 430 metric tons per year. This is roughly consistent with estimates made in the 2006 UNEP trade report.